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Treatments to Increase the Final Fruit Size on Satsuma 'Clausellina'

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Abstract. **In order to determine the best treatments to increase the final size of the fruits of the satsuma 'Clausellina' [*Citrus unshiu* (Mak.) Marc.], the following experiments have been conducted: 1. Hand-thinning: Two degrees of thinning: 33 % and 66 % of flowers-fruits present, in four periods, between flowering and ripening. 2. Pruning: Removing 30 % and 50 % of the canopy in three periods between flowering and summer. 3. Chemical products: Applications of several growth regulators after June drop. The effects of these treatments on fruit size and yield will be presented and discussed.**

The term 'fruit quality' in citrus is a subjective concept dependent on the market demand, and involves a number of features such as size, colour, flavour, easy-peeling, seed content, etc. but, doubtless, in the present circumstances, the fruit diameter is a crucial factor to determine quality, therefore, an 'adequate size' significantly improves quality and consequently, higher prices can be reached in the market.

Very unusually there are problems with large size fruits. Serious problems appear mainly with small size fruits, that some varieties specialy on mandarin group (easy-peeling) tend to produce.

Genetic, environmental and cultural factors have an incidence on fruit size, and among the latter, the nutrient condition (Jones et al., 1970; Guardiola, 1980; Plesis, 1980), irrigation, (Hilgeman, 1977; G. de Barreda et al., 1982), girdling (Cohen, 1977, 1984; Hochberg et al., 1977; Agustí et al., 1989,1991), pruning (Boswell and Cole 1978; Lewis and Mc Carty, 1973), flowering control (Guardiola, 1987; Guardiola et al., 1978; Agusti et al., 1982; Goldschmidt and Monselise, 1988), growth regulators (Guardiola et al., 1988; Agustí and Almela, 1991), and chemical or manual thinning (Hirose, 1982; Wheathon, 1982; Zaragoza et al., 1990; Ortolá et al., 1991) can influence the final size of the fruit under suitable conditions. However, the results obtained not always come up to our expectations, doubtless because there are many factors, sometimes uncontrolled, or unknown, that can influence the commercial fruit size (Guardiola, 1987).

We are reporting on the results of a number of experiments through which the increase of fruit size has been attempted by three different ways: 1. manual thinning, 2. pruning and 3. application of growth regulators.

Work has been carried out on the satsuma 'Clausellina' [*Citrus unshiu* (Mak.) Marc.] for two reasons: one, because the large size fruits obtain very high prices in the market, but those of smaller size, are rejected by the consumer; the other, because the size of the adult plant is small, approximately 2 m in diameter, and this allows to control, quite exactly, many parameters such as number of flowers, number of fruits set, final number of fruits, diameter of main and secondary limbs, etc.

Material and Methods

To conduct the experiments, an orchard planted with 'Clausellina', clon INIASEL, was selected in Sagunto (Valencia). The plants, grafted on Cleopatra mandarin (*C. reshni* Hort. *ex.* Tan.), were planted in 1983 at a spacing 2 x 2 m. The canopy diameter was about 1.70 m.

1. *Manual thinning of fruits.* Manual thinning was done in 4 periods of the year: 1. by the end of April during full bloom, 2. by the beginning of June, on fruit set (diameter of fruitlets 15.2±1.33 mm) , 3. by the beginning of July, after June drop, (diameter 28.8±1.51 mm) and 4. by the beginning of September (diameter 51.4 ± 1.33 mm).

Thinning was done with two degrees of severity, by eliminating 33% (severity L), or 66% (severity H) of flowers-fruitlets present in each period, so that 1 or 2 flower-fruitlets were removed, respectively, from every 3, from all the branches. At the beginning of the experiment the trees had about 1500 flowers.

Eight replications were made for each treatment (season and thinning degree), taking one tree per replication, and 8 trees, without thinning, were used as control (C).

Before harvesting, made at the end of September, diameter and weight of the fruits were measured by randomly collecting 30 fruits per tree. Fruits existent in each tree were counted, as well.

This experiment was conducted in 1988.

2. *Pruning.* Pruning was performed in three seasons coincidental with the three initial periods in the previous experiment: 1. full bloom, 2. fruit set, and 3. after the June drop. The pruning was done with two severity degrees: approximately 30% (severity L), or 50% (severity H) of foliage was eliminated. As a previous step, was determined the sum of the diameters of all limbs of the plant, between 1 and 3 cm diameter, and based on these data, the elimination of branches was made selectively, so that the sum of their diameters were equal to 30%, or 50% of the whole determination.

Twelve replications were made for each treatment (season and severity degree) taking one tree per replication and 12 trees without pruning were used as control (C).

This experiment was conducted in 1989.

3. *Growth regulators.* The treatments were applied, after the June drop. At this time the diameter of the fruitlets was 20.8 ±0.13 mm. Products and amounts used were as follows:

1. 2,4-dichlorophenoxyacetic acid (2,4-D) 75 ppm, 2. 2,4 dichlorophenoxypropionic acid (2,4-DP) 75 ppm, 3. Naphthalene acetic acid (NAA) 100 ppm, 4. Naphthalene acetic acid (NAA) 200 ppm, 5. 3,5,6-TRICHLORO-2-PYRIDYL-OXYACETIC acid (3,5,6-TPA) 10 ppm, 6. 3,5,6-TRICHLORO-2-PYRIDYL-OXYACETIC acid (3,5,6-TPA) 20 ppm, 7. 2,4-DP 75 ppm + NAA 100 ppm, 8. Control (unsprayed).

The entire trees were sprayed with a hand gun and the volume

applied was about 1.5 l per tree.

From each treatment, 9 replications were made. The statistical design, as well as the determinations made were similar to those in the previous experiment. The thinning effect of each product was determined counting the fruits dropped, and prior to harvesting, the internal and external fruit quality was determined by randomly taking a sample of 30 fruits per tree.

The experiment was conducted in 1991.

Results and Discussion

1. *Manual thinning.* As observed in Table 1, the more severe thinning at different stages of fruit development (treatment 2H, 3H and 4H), produced fruits with larger sizes. The increase in fruit diameter respect to the control oscillate between 2.5 to 3 mm.

The less severe thinning (treatments 2L, 3L and 4L) did not show any significant differences in the final fruit size with respect to the control.

Removal of flowers (treatments 1H and 1L) was also ineffective to increase final fruit size.

Figure 1 shows that the best treatments (2H and 3H) produced a higher rate of fruits with larger diameters, if compared with the control fruits.

The effect of thinning on the increase in fruit size, is probably due to a reduction in the competition between fruits, resulting in a higher growth. However for the reduction of the competition effect to be become evident, thinning must be severe.

Thinning at full bloom, did not produce any effect on final fruit size, probably because most ovaries fall during the fruit set period and the elimination of some of them, favours fruit set of the others. Therefore, the number of fruitlets set after the removal of flowers, was similar to that of the control plants.

Doubtless, the effects of treatments would have been more remarkable of the smaller fruitlets, or those presenting poorer conditions would have been eliminated, instead of randomly eliminating 33% of 66% of fruitlets.

On the other hand, it was proven that the most severe and late thinning, tend to significantly diminish the number of fruits harvested, whereas thinning during flowering scarcely has an influence on final fruit number.

Consequently, a sharp reduction in yield was observed in trees severely thinned during the period of fruit development. In these treatments, the increase in fruit weight obtained was insufficient to compensate for the resulting reduction in the number of fruits harvested. However, the improvement in commercial quality of the fruits, may compensate this loss.

2. *Pruning.* Differences between pruning treatments are smaller and the diameters obtained by the most favorable treatments resulted in a difference of about 2 mm if compared with those of the control. (Table 2).

Pruning in June and July (periods 2 and 3) provide the best results. The elimination of branches resulted in a decrease in the

Table 1. Manual thinning of fruit.

Treatments period and severity		Fruits diameter mm[z]	Fruit weight g[z]	Yield Kg/tree[y]
1-L Full bloom	33%	56.3abc[x]	79.5bc	20.8abc
1-H Full bloom	66%	55.6bc	78.5c	23.5a
2-L Fruit set	33%	55.2c	77.1c	20.1abc
2-H Fruit set	66%	58.2a	89.9a	16.1cde
3-L June drop	33%	56.7abc	83.5abc	16.9bcd
3-H June drop	66%	58.0a	87.2a	14.0de
4-L September	33%	55.5bc	78.1c	17.9bcd
4-H September	66%	57.7ab	86.3ab	11.7e
C Control		55.4c	77.9c	21.5ab

[z] Means of 240 fruits.
[y] Means of 8 trees.
[x] Means of differents letters are significantly different at 5% level by Ducan's Multiple range test.

Table 2. Pruning.

Treatments period and severity		Fruits diameter mm[z]	Fruit weight g[z]	Yield Kg/tree[y]
1-L Full bloom	30%	55.3bc[x]	75.8c	24.0b
1-H Full bloom	50%	55.8abc	81.9ab	25.4b
2-L Fruit set	30%	56.5ab	82.4ab	22.9b
2-H Fruit set	50%	57.0a	84.2a	20.2b
3-L June drop	30%	56.8a	79.4abc	24.1b
3-H June drop	50%	56.3abc	80.3abc	22.8b
C Control		55.0c	77.6bc	37.9a

[z] Means of 240 fruits.
[y] Means of 8 trees.
[x] Means of differents letters are significantly different at 5% level by Ducan's Multiple range test.

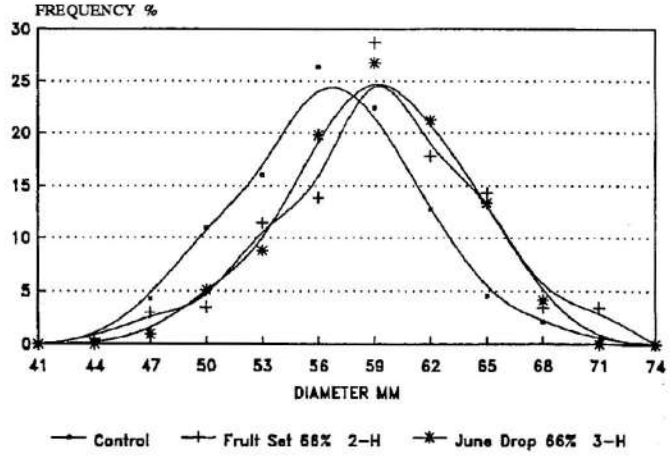

Figure 1. Manual thinning. Distribution of fruit size.

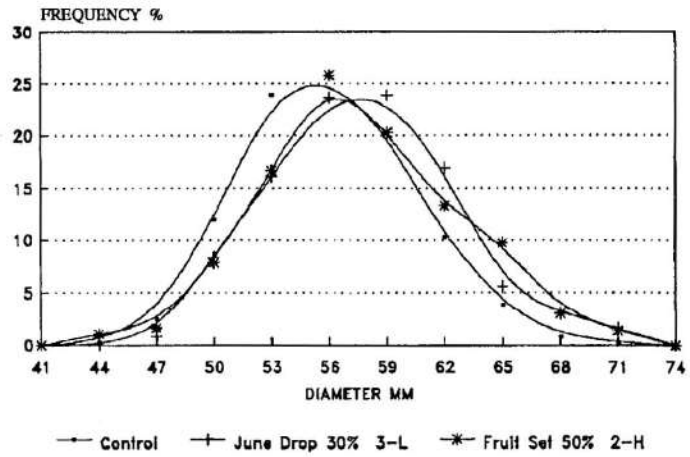

Figure 2. Pruning. Distribution of fruit size.

number of fruits per tree, so that the competition among fruitlets is reduced. Moreover, after pruning, a subsequent vegetative growth occurs, being able of substituting the material eliminated and of providing the necessary nutrients to the remaining fruitlets.

Another consideration, also having a favorable influence, is that the branches are cut off following a selective criterium, i.e., eliminating those appearing weak and that tend to produce poorer quality fruits.

As shown in Figure 2, the most favourable treatments increase the rate of fruits with larger sizes, entailing a hihger consumer demand.

Table 2 shows that any pruning method induces a sharp reduction in number of fruits harvested, and the increase in fruit weight, provided as consequence of pruning, was not sufficient to compensate the decrease in yield. However, under the economic viewpoint, the pruning method may be profitable.

3. *Growth regulators.* Results obtained with the growth regulators were more remarkable and promising than those from previous experiments. Differences in average diameters of fruits between the control and the most favourable treatments were of about 4-5 mm (Table 3) which is highly significant from the commercial viewpoint.

The effects of the products utilized were variable, and conditioned by the effect of hormones on fruit growth and the indirect effects due to thinning.

Thus, the NAA (200 ppm) provoked a thinning close to 40% of the fruitlets, whereas 3,5,6-TPA (20 ppm) and the mixture of 2,4-DP (75 ppm) and NAA (100 ppm), produced about 30% fruit loss.

This suggests that the effect on the fruit size in the case of NAA (200 ppm) has been basically due to a reduction of the competition as a consequence of thinning.In the other two treatments, the effects observed, cannot be explained solely by the thinning effect.

In the rest of treatments, 2,4-D (75 ppm), 2,4-DP (75 ppm), 3,5,6-TPA (10 ppm) and NAA (100 ppm) the effect on size, if any, has been due to the effect of the hormones on fruit growth.

Growth regulators which produced thinning tend to drop selectively the smaller fruits at the moment of application. This effect may explain the differences obtained between NAA (200 ppm) spray and the manual thinning (experiment 1) in which the elimination of fruits was not selective.

Growth regulator treatments did not modify other fruit quality parameters, such as density, peel thickness, juice content, pulp rate, soluble solids, or acidity.

Figure 3 shows the notable differences between the occurrence of larger diameters if comparing treatments 3,5,6-TPA (20 ppm) and 2,4,5-DP (75 ppm) with the control.

On the other hand, yield was not altered by various treatments (Table 3) except in the case of NAA (200 ppm) althought there were not significative differences.

Table 3. Growth regulators.

Treatments products and amount	Fruits diameter mm[z]	Fruits weight g[z]	Average of thinning fruits%[y]	Yield Kg/tree[x]
1.-2,4-D 75 ppm	56.6cd[w]	84.7cd	3e	21.8a
2.-2,4-DP 75 ppm	58.4bc	91.8bc	5e	21.1a
3.-NAA 100 ppm	58.1bc	90.3bc	14d	23.5a
4.-NAA 200 ppm	58.3bc	91.2bc	37a	18.1a
5.-3,5,6 TPA 10 ppm	58.1bc	90.7bc	20c	20.9a
6.-3,5,6 TPA 20 ppm	60.5a	99.9a	30ab	22.2a
7.-2,4-DP 75+NAA 100 ppm	58.7b	92.9b	29bc	21.7a
8.-Control	56.0d	82.3d	0f	21.4a

[z] Means of 270 fruits.

[y] Date were converted to arc sin $\sqrt{\text{percentage}}$ percentage for statistical treatment.

[x] Means of 9 trees.

[w] Means of differents letters are significantly different at 5% level by Ducan's Multiple range test.

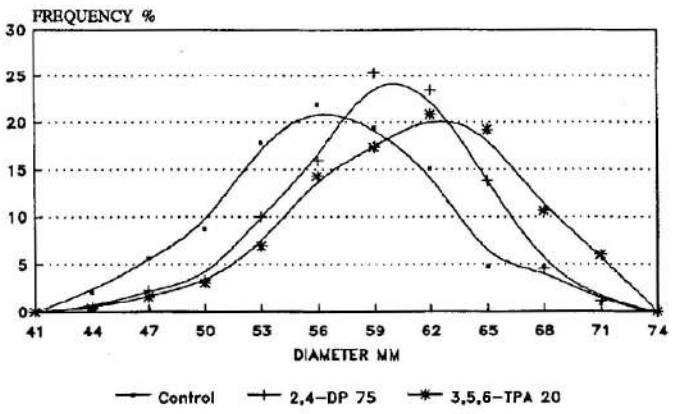

Figure 3. Growth regulators. Distribution of fruit size.

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